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OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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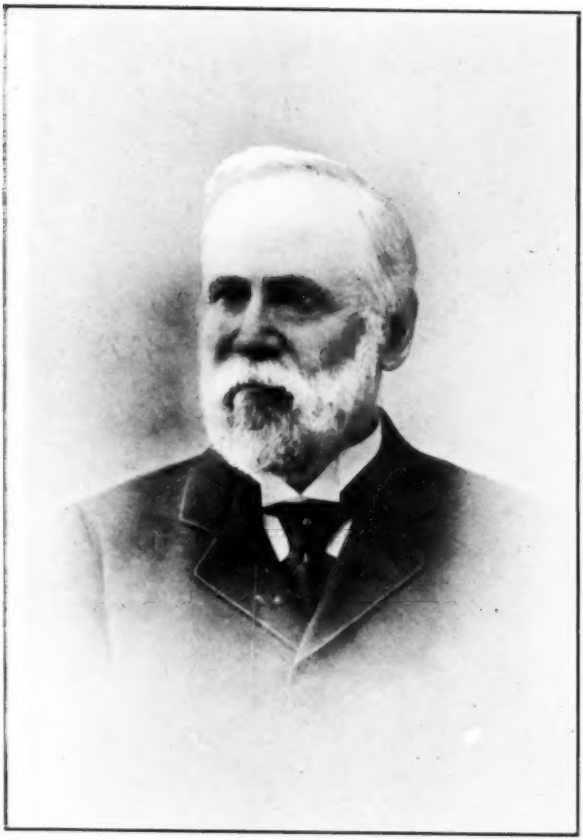

CHARLES AUGUSTUS YOUNG

B. DECEMBER 15, 1834; D. JANUARY 3, 1908.

(See Page 27).

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PROGRESS IN ASTRONOMY AND ASTROPHYSICS DURING 1907

BY C. A. CHANT

(PRESIDENT'S ADDRESS, ANNUAL MEETING, JANUARY 14, 1908.)

IT is customary for the retiring president to deliver an address to the Society, but after reading the brilliant address delivered from the presidential chair of the British Association last year by the eminent astronomer Sir David Gill, wherein the present condition and the prospects for the future, of astronomy, were discussed by one whose life work has been so effective in placing modern astronomy where it now is, I felt inclined to omit the usual statement of the work of the year just gone. But remembering that mine is rather a historical than a critical review and that this is my last appearance in this position, having been president of the Society for the exceptionally long period of four years, I decided to go ahead, and then gladly make way for my successor.

On looking over the field at the close of the year one always observes great gaps made by death in the line of the workers, and the year 1907 certainly has a heavy list of the fallen.

Among these I would mention a few. One of the severest losses was that of H. C. Vogel, the late director of the Astrophysical Observatory at Potsdam, Germany, who died on August 14, aged 65 years. Vogel was the first definitely to apply the method now used for the determination of the velocity of the stars in the line of sight, *i.e.*, to photograph the star's spectrum with an instrument constructed for this special purpose. One of his early triumphs was the experimental investigation of the nature of the variations of the star Algol. This was the first discovery of a spectroscopic binary. Vogel's entire career as a spectroscopist was very distinguished. He was an Honorary Fellow of our Society for many years.

Another regretted loss is that of Maurice Lœwy, the director of the Paris Observatory, who suddenly passed away on November 15. Lœwy is perhaps best known to us through the series of charts of the Moon which he issued in conjunction with Puiseux; but he had rendered great assistance in many other branches of the work at the Observatory, particularly in the laborious preparation of star catalogues, the perfecting of the equatorial coudé and the minute study of the errors of instruments. Lœwy was born in 1833, and was an Honorary Fellow of our Society.

In addition to these I shall mention only three:—Alexander S. Herschel, second son of Sir John Herschel and an authority on meteoric astronomy; J. K. Rees, former director of Columbia University Observatory; and H. C. Russell, who was for forty years prominent in the scientific life of New South Wales, having been from 1870 Government astronomer and director of the Sydney Observatory. Among other things he organized the meteorological service. When he assumed office there were five rain-guages in the colony, when he retired there were 2000.

THE SUN.

Steady progress has been made in the study of our great source of energy, though no startling developments are reported. On January 14 there was a total eclipse, the path of totality being across central Asia. A number of expeditions were sent to

Samarkand to observe it, but, as was feared, the atmospheric conditions were unfavorable. During the time of the eclipse a heavy snow-storm prevailed, and only some meteorological and photometric observations were secured. At Dehra Dun, in India, and at Zi-ka-wei, in China, a partial eclipse was well seen and observations were made.

Although the maximum of the 11-year period had certainly passed, the amount of spottedness on the Sun's disc was very considerable, an exceptional feature being the number of groups of spots visible to the naked eye.

Additional elements have been recognized in the Sun. Professor Fowler, of South Kensington, has demonstrated the probable presence in the chromosphere of silicon, and he has found a terrestrial origin for the numerous short hazy lines known as "band" lines in the sun-spot spectra, these being apparently part of an extensive "fluting" spectrum from a compound of magnesium and hydrogen. Professors Schwartzschild and Runge, of Göttingen, from observations made in Algeria at the time of the total eclipse of August 30, 1905, find the presence in the corona of yttrium, zirconium, lanthanum, cerium, neodidymium and ytterbium. Thus is the family connexion between the Sun and the Earth shown to be even more intimate.

Ceraski, of Moscow, determined the relative intensities of the light at the Sun's limb and of the atmospheric illumination very near the limb, and found a mean ratio of 34·9, a result surprisingly low. Ceraski points out that his method might be used as a term in evaluating the relative intensity of the corona, the proposal being to compare the corona with a standard lamp during an eclipse, and then afterwards compare the lamp with the atmospheric illumination at a determined point in the sky. It may be recalled that the same astronomer obtained the stellar magnitude of the Sun by comparing it with Venus, and then Venus with a fixed star.

From 151 plates of Eros taken at Greenwich with the Astrographic 13-inch Refractor and 103 with the Thompson 26-inch Refractor between October 14, 1900 and January 15, 1901, a

new value for the solar parallax has been determined. It is $8''{\cdot}800 \pm 0''{\cdot}0044$, which agrees very well with the value $8''{\cdot}802 \pm 0''{\cdot}005$ published by Sir David Gill in 1897.

The third meeting of the International Union for Coöperation in Solar Research was held at Meudon in May 1907. The first meeting was at St. Louis in September 1904, the organization having originated with Professor Hale. Distinct progress was shown at the last meeting, and undoubtedly most important results will come from this commendable union in attacking this great problem. Before long I hope to see Canada having a distinct share in this work. The next meeting will be held in 1910 at Mt. Wilson in Southern California, where is located the Carnegie Solar Observatory.

At this great institution Professor Hale has erected a novel form of cœlostat telescope. The cœlostat mirror is mounted on a steel tower 60 feet high, while a second mirror will reflect the beam down on a 12-inch object glass of focal length 60 feet, and this will focus the image on the slit of the spectroheliograph or spectrograph, these two instruments being underground and therefore at an even temperature. In order to avoid distortion, each of the mirrors is 12 inches thick and is silvered on both faces. The grating of the spectrograph will have a diameter of 12 inches, and it will be used in the study of the Sun's rotation and in the photography of sun-spot spectra.

THE MOON.

Much interest has centered for many years about the little crater Linné in the Sea of Serenity, since it would appear that if any changes have taken place on the surface of the Moon they have been in the neighborhood of this object. During a lunar eclipse the white spot surrounding the crater seems to enlarge, a result explained as due to a deposition of hoar frost. Dr. Wirtz points out that an apparent enlargement of the white spot can be produced by interposing a shade glass between the telescope and the eye, and from this he argues that the enlargement seen during an eclipse might be simply a subjective phenomenon due to the diminution of light. Prof. W. H. Pickering, however, contends

that while this effect undoubtedly exists, it is much smaller than that observed during an eclipse, and also that the spot is larger after the passing of the eclipsing shadow than before it.

As an illustration of the difficulty of determining the physical condition of a celestial body one may refer to recent estimates of the temperature of the Moon. As a result of investigations relating to the reflexion of heat radiation from various mineral substances, W. W. Coblentz concludes that the apparent temperature of the Moon's surface is due chiefly to the radiation reflected from it, little of it penetrating into the Moon's body, and hence the actual temperature may fall very low, probably to $-225°$ C., in accordance with Langley's estimate. On the other hand F. W. Very, who formerly acted as assistant to Langley, contends that the greater part of the radiations received from the Sun are not simply reflected, but that they are first absorbed by the substance of the Moon and then given out as heat. He suggests that the temperature may even reach a maximum of 100° C.

THE PLANETS.

During the year much interesting work has been done on the planets. During the summer there was an opposition of Mars very favorable for observation, and exceptional interest was shown both by astronomers and the general public. In the discussions the central figure is Percival Lowell, director of the Lowell Observatory, Flagstaff, Arizona, who has carried on his observations with enthusiasm, patience and skill, and has stated his views in an interesting and able manner. There are two problems, (1) To determine the facts, especially to secure accurate delineations of markings, (2) To interpret the observed phenomena. As is well known drawings of the planet's disc, made by Lowell and some others, show an abundance of fine markings, while other astronomers, equally accustomed to close observation, are quite unable to see these lines. During the summer Professor Newcomb endeavored to show, from considerations of aberration and diffraction in the telescope, that it is simply impossible to see such fine lines as appear on many drawings; but this view has been vigorously combated by Lowell, both from the theoreti-

cal and the practical side. "Who shall decide when doctors disagree?"

Great interest was aroused in the announcement that Lowell's very capable assistants, Messrs. Lampland and Slipher, had actually photographed the so-called canals. Extremely creditable photographs were taken in 1905, and again last year, and an expedition in charge of Professor Todd was sent to South America, at the expense of Professor Lowell, to secure observations and photographs at a more suitable station. Reproductions of a number of these have appeared in some of the magazines, and recently some of the original negatives, with transparencies from them were exhibited in Boston. Professor Bailey, of the Harvard Observatory, reports that while they show nearly as much as is seen by conservative observers of Mars, he was unable to see any of the long, straight, sharply defined canals shown on many drawings, and no sign of doubling.

Two French observers, Messrs. Jarry-Desloges and G. Fournier, observing from the summit of the Revard, at an elevation of 1550 metres, reported seeing the doubling of the Solis Lacus. They also saw a number of canals, the Ganges appearing double. The Abbé Th. Moreux agrees with Lowell as to the bolder features, but doubts the objective reality of the fine rectilinear canals of which Lowell has enumerated 420. The Abbé has never seen any of the alleged oases, which are said to mark the intersection of the canals. From his series of observations during 1905 he concludes that the transparency of the Martian atmosphere has been overrated in the past. On several occasions cloud formations obscured detail on the planet's surface. M. Sola, of the Fabra Observatory (Barcelona), also detected atmospheric changes on the planet. He saw a "lac" at the interection of the canals Phison and Orontes, and the Euphrates, though perfectly visible, was always diffuse.

Calculations of the temperature of Mars, deduced from the relative distances of Mars and the Earth from the Sun give $-33°$ F. as the mean temperature of the planet. Lowell, however, from consideration of the albedoes of the planets, the screening

effect of clouds, the blanketing effect of the atmosphere, etc., deduces the value 72° F., if the heat were retained there as well as it is here. As the retention is greater in the case of the earth, this value is considerably reduced, a mean temperature of about 47° F. being obtained. This result is important in considering the question of life upon Mars.

It is this latter aspect of the problem which appeals so strongly to the popular imagination, and the evidence for or against life on the planet comes from our interpretation of the observed markings. Professor Lowell does not hesitate to attribute an artificial origin to the canals and argues indeed that life on Mars must be strenuous and highly developed. As a rule, however, I believe astronomers are rather inclined to the opposite view, and will remain sceptical until further evidence is forthcoming.

The question of the period of rotation of Venus is an important one. Of late years, largely through the observers at the Lowell Observatory, the longer period of 225 days, the same as its sidereal period, has been looked on more favorably, but the observations of Messrs. Hansky and Stefanik on Mont Blanc, made under nearly perfect atmospheric conditions, incline to the shorter period. One set of observations gave $23^{h}\ 20^{m}$ and another $23^{h}\ 25^{m}$. Denning, however, sums up the results, and concludes that after the earnest application of observers during three centuries, the problem of the confiiguration and the axial rotation of the planet remains unsolved.

Jupiter's sixth and seventh satellites were discovered at the Lick Observatory from photographs taken about the end of 1904 by Professor Perrine, and some interesting work has been done on them since that time. At the Harvard Observatory Miss Leavitt has found the image of the sixth satellite on two plates taken in 1894 and on nine taken in 1899, while at the Royal Observatory at Greenwich the two satellites were identified on 55 plates taken recently with the 30-inch reflector. These allowed the orbits to be mapped with accuracy.

During the last year the planet Saturn was in that portion of its orbit where the edge of its ring is presented to the Sun and the earth, and the question arose whether the ring is ever invisible in our largest telescopes. I have not heard all reports, but so far the ring could always be seen. The most remarkable observation made on Saturn was that reported from Lick, and confirmed at Flagstaff, that bright knots were seen on the ring, symmetrically placed on each side of the ball. V. M. Slipher of the Lowell Observatory, Flagstaff, publishes a spectrographic study of the planet. He finds five decided absorption bands in the spectrum of the ball, though they are entirely absent from that of the rings. This points to the conclusion that if the rings possess any atmosphere at all it is much rarer than that surrounding the ball. No trace of absorption due to aqueous vapor was to be seen on the spectrograms.

The discovery of minor planets or asteroids goes on unchecked, and up to June 9, 1907, 635 of them had received permanent numbers. Three of these are especially noteworthy as they move out in their orbits beyond Jupiter's distance from the Sun. These three are 1906 *TG* or No. 588, 1906 *VY*, 1907 *XM*, all discovered at Heidelberg, and to them have been given the names Achilles, Patroclus and Hector.

Dr. P. Stroobant, of the Royal Observatory of Belgium, discusses the first 512 of these planets, and shows that a decided maximum occurs between the limits marked by circles whose radii are 2·55 and 2·85 times the earth's mean distance from the Sun. In this annulus 199 of the asteroids revolve. Nearly all the asteroidal matter is concentrated near to the middle of this ring.

COMETS.

During 1907 five comets were discovered. The first, 1907 *a*, was reported by Giacobini at Nice on March 9; 1907 *b* was found by Mellish at Madison on April 14, though it had previously been seen by Grigg, at Thames, New Zealand; Giacobini discovered 1907 *c* on June 1; Daniel, of Princeton, 1907 *d* on June

14; and Mellish 1907 *e* on October 13. Daniel's comet was the brightest seen for many years, being visible to the naked eye for a month or more. Valuable spectrographic work on it was possible. The discoverer of the second and fifth comets well deserves a complimentary reference. John E. Mellish is but a youth living at Cottage Grove, near Madison, Wisconsin. He made his own six-inch reflector, and on discovering his first comet, which was of the 11th magnitude, he walked five miles to report it to Professor Comstock, of the Washburn Observatory. Surely we may expect a distinguished career from this brilliant observer.

It is expected that Halley's comet, which returns every 76 years, will make its perihelion passage in the first half of May 1910, at which time it will be at a distance from the Sun 0·59 times that of the earth. The comet will be visible to the naked eye some months before this time.

METEORS.

The heights, lengths of paths and velocities of ten large meteors observed in England in 1906 have been reported by Mr. Denning. He finds that at the commencement of visibility the heights ranged from 59 to 89 miles; at disappearance, from 22 to 56 miles. The longest path was 72 miles and the shortest 24 miles, while the velocities were between 15 and 30 miles per second.

A valuable discussion on the nature of meteor trains is given by Prof. C. C. Trowbridge. He believes that at a height between 50 and 60 miles is a layer favorable to the production of the peculiar glow constituting a meteor train; also, that the train itself is probably a tube of gas and particles of meteor dust rendered phosphorescent by some temperature or electrical effect produced by the meteor's passage.

THE STARS.

The grandest problem in astronomy is the structure of the universe. Year by year our knowledge of the stars increases

and we hope that at some time in the future our successors will be able to formulate a comprehensive view of the distribution of the worlds through space.

Perhaps the most striking advance is the demonstration that the proper motions of the stars, instead of being wayward and lawless, are distinctly systematic. This view was put forward by Kapteyn, of Groningen, but it has been worked out in a very elegant manner by A. S. Eddington, who for his work received the gold medal of the Royal Astronomical Society. He found that the motions of the stars, instead of being haphazard, could be classified into two "drifts" in relative motion one to the other. The stars of drift i. have a common motion, relative to the Sun, away from a point near R. A. 18 h., declination +18°, while those of drift ii. move from R. A. 7 h. 30 m., declination +58°. The velocity of those in the first drift relative to the Sun is much greater than that of the second, the ratio being about 17 to 5. We thus appear to have two great groups of starry worlds moving through space in almost exactly opposite directions but with very different velocities with respect to us.

This highly interesting and important result has been urged as an argument against Dr. A. R. Wallace's view as to the unique position of our earth in the universe, it being claimed that the new discovery shows that we have in reality two universes of stars. This would render Dr. Wallace's position untenable unless it be assumed that the Solar System is the centre about which both universes oscillate. Dr. Wallace discusses Eddington's paper. Assuming with Kelvin a single vast stellar universe, slowly condensing towards its centre of gravity, the component stars would move in ellipses or spirals of varying degrees of eccentricity and inclination to the mean orbit. If, further, the Sun is placed near the centre, Wallace contends that the stars would have forward or retrograde motions which he thinks would exhibit the motions observed. It is hard to see, as Eddington points out, how this can fulfil the required conditions, as the motions which the stars would then have would be essentially haphazard.

The great Astrographic Catalogue, launched just twenty years ago, is steadily moving forward though it will still be many years before it comes to port. Progress is reported at almost every coöperating observatory, and we recently received the first two volumes prepared at the Oxford University Observatory. To this observatory was assigned the section between declinations $+24°$ and $+32°$. The first volume gives the measurement of 65,730; the second, 66,718 stars, and as there are to be six more volumes, the total number of stars will be immense. Great credit is due Prof. H. H. Turner, under whose direction the work at Oxford is being done, who with scanty resources is bringing to completion so rapidly his portion of the work.

In double star observations many new discoveries have been made, perhaps the greatest progress being made at the Lick Observatory by Professor Aitken, who is continuing his great survey of the sky. But the most important development was the publication of the great General Catalogue on which Professor Burnham has been engaged for so many years. It gives the coördinates of 13,665 stars, their position angle and distance at a given epoch, the magnitudes of the components and other information. It is exceptionally complete, and everywhere is seen the results of the author's enthusiasm, long experience and intimate acquaintance with his subject. This publication will lead to better organization and husbanding of resources.

The crop of spectroscopic binaries during the year was a good one, especially by the Lick Observatory, though our own National Observatory at Ottawa has contributed its share. A very interesting binary is β *Arietis*, discussed by Ludendorff, of Potsdam, who finds for it a period of 107 days, a semi-major axis of 22,880,000 km. and an eccentricity 0·88, the greatest yet discovered.

In researches on variable stars the Harvard Observatory retains its premier position. In vol. 47, part 1 of the *Annals* Mrs. W. P. Fleming gives a list of 222 new ones of long period, discovered by photography by means of spectral peculiarities. It

is stated that no star of type *Md* (the third type with hydrogen lines bright) has been found which is not variable. In part 1 of vol. 55 of the *Annals* is a Second Catalogue of variable stars prepared by Miss A. J. Cannon. Variable star catalogues extend back to 1844, when a list of 18 variables appeared, compiled by Argelander. In the present catalogue are 1957 variables, this including 500 variables found in globular clusters but not 1800 in the Magellanic Clouds. In all 3750 stars are known to be variable, of which 2900 have been discovered at the Harvard Observatory.

The method of discovering photographically variable stars by superposing a negative and a positive copy of a similar negative taken at a different epoch is leading to good results. Many new variables have been discovered at Harvard Observatory, where the method originated, and a systematic examination of the entire sky, as photographed at that institution is now under way. Circular 127 reports 14 new variables in two regions examined. Circular 130 contains a list of 71. Comparing the number newly discovered with the number known to exist in the regions examined, Professor Pickering concludes that in the northern regions probably one-third, and in the southern one-half of the variables yet remain to be discovered. J. A. Parkhurst, of the Yerkes Observatory, has published the results of the investigation of 12 variables of long period, and from the Laws Observatory of the University of Missouri come the preliminary results of observation of 33 variables.

Reference should be made to the researches on stellar parallax made with the heliometer at Yale Observatory, chiefly by Dr. F. L. Chase. Of the 163 stars examined the parallaxes range from $-0''{\cdot}13$ to $+0''{\cdot}20$, the number of negative parallaxes being 36. The results show a distinct connexion between parallax and stellar motion, while that between parallax and magnitude, though fairly evident, is not so marked. Kapteyn had deduced the result that stars whose spectra are of type II. have a larger parallax, but this conclusion is not supported by the Yale results. As is well known, the star with greatest known parallax is

α Centauri, with a value 0″·750, corresponding to a distance of 4⅓ light years. Considering the width of the net set to catch the stars it is probable that there are none nearer than this, and our views as to the scale of the stellar universe are assuming fairly definite shape.

LONGITUDE BY WIRELESS TELEGRAPHY.

Before the development of the electric telegraph the accurate determination of longitude was very difficult, but since then it has been comparatively simple. It has recently been shown that in the absence of the ordinary telegraph the wireless method may be used. This was well shown in a determination made by Th. Albrecht, of the difference of longitude between Potsdam and the Brocken, at a distance of over one hundred miles. The method was found quite feasible, and very useful for places not connected by wire. As these two places were connected by the ordinary telegraph, it was possible to compare the precision of the two methods. In general the difference was found to be of the order of $\frac{1}{1000}$ second. Any variation in the amount of energy used made no appreciable difference, and the duration of transmission was negligible, but atmospheric influences were more effective than with the old method. It is quite probable that this method may be found useful in some of the geodetic work in Canada.

THE WORK OF THE SOCIETY DURING THE YEAR.

For some years the interest in astronomy has been developing, and it certainly received a marked increase in 1907. In my address a year ago I stated that a section of our Society had been organized at Ottawa. During the year similar organizations were formed at Peterborough and Victoria, B.C.

The meetings at Toronto have shown no abatement of interest, and it is especially encouraging to see some of the newer members taking active part in the work. The papers presented here were numerous, interesting and valuable. At Ottawa, owing to the presence there of the constantly growing staff of the Dominion Observatory, the papers have had a more technical

aspect, and some of them have been distinct contributions to science. At Peterborough and Victoria the work has been of a more elementary nature, but in both places the membership is creditably large and representative of the educational side of the community. "Let knowledge grow from more to more."

Much of this increase in interest in our work is due, I think, to the publication of the Society's *Handbook* and JOURNAL. The latter appeared bi-monthly during 1907. The six numbers issued contain nearly 400 pages of well-printed, and I hope well-edited, matter. Both at home and abroad it has been declared a credit to Canada, and in its production all portions of the Society have coöperated. It is a matter of regret to me that up to the present it has not been found possible to suggest changes in the Society's constitution made necessary by our expansion, which are acceptable to all, but whatever is finally adopted I hope there will be the same practical coöperation in astronomical work and union, in support of the JOURNAL.

THE THEORY OF LEAST SQUARES *(Concluded)*.

By W. F. King

FOURTH PROOF.

IT is assumed, as in the third proof, that the elementary errors are equal in magnitude and that they all enter, indifferently plus and minus, into each observation.

As before the frequency of the error $v = mdv$, when there are $2n$ elementary errors altogether, is the coefficient of x^{n-m} in $(1+x)^{2n}$.

The total number of possible errors is 2^{2n}. Therefore the probability of the occurrence of the error mdv is the coefficient of x^{n-m} in $\frac{1}{2^{2n}}(1+x)^{2n}$, that is

$$\frac{1}{2^{2n}} \frac{\lfloor 2n}{\lfloor n-m \; \lfloor n+m}$$

It may be proved that

$$\lfloor x = x^{x+0\cdot5}\, e^{-x} \sqrt{2\pi} \times \left(1 + \frac{1}{12x} + \frac{1}{288x^2}\right).$$

(Laplace, *Théorie Analytique des Probabilités*).

Hence we have for the error $v = mdv$, probability

$$= \frac{1}{2^{2n}} \frac{(2n)^{2n+0\cdot5}\, x^{-2n}\, \sqrt{2\pi}}{(n-m)^{n-m+0\cdot5}\, e^{-(n-m)}\, \sqrt{2\pi}\, (n+m)^{n+m+0\cdot5}\, e^{-(n+m)}\, \sqrt{2\pi}}$$

$$\times \left(1 + \frac{1}{24x} + \ldots\right)\left(1 + \frac{1}{12(n+m)} + \ldots\right)^{-1}\left(1 + \frac{1}{12(n-m)} + \ldots\right)^{-1}.$$

Reducing, we have probability

$$= \frac{1}{\sqrt{n\pi}} \left(1 - \frac{m}{n}\right)^{-(n-m+0\cdot5)} \left(1 + \frac{m}{n}\right)^{-(n+m+0\cdot5)} \left(1 - \frac{1}{8n}\right) \text{ nearly.}$$

It is easily shown that the logarithm of

$$\left(1 - \frac{m}{n}\right)^{-(n-m+0\cdot5)} \left(1 + \frac{m}{n}\right)^{-(n+m+0\cdot5)}$$

$$= -\frac{m^2}{n} - \frac{m^2}{n^2}\left(\frac{1}{6}\frac{m^2}{n} - \frac{1}{2}\right) - \frac{m^4}{n^4}\left(\frac{1}{15}\frac{m^2}{n} - \frac{1}{4}\right) - \&c.$$

This, if m is small compared with n, may be taken as equal to $-\frac{m^2}{n}$. The factor $\left(1-\frac{1}{8n}+\ldots\right)$ may be put equal to unity.

Therefore, probability of error mdv

$$= \frac{1}{\sqrt{n\pi}}\, e^{-\frac{m^2}{n}}.$$

Now $\frac{m^2}{n} = \frac{(mdv)^2}{ndv^2} = h^2v^2$ if we put $\frac{1}{n}$ for $\sqrt{n}\,dv$.

Therefore, probability $= \frac{h}{\sqrt{\pi}}\, e^{-h^2v^2}\,dv$.

This shows that the probability curve is the limiting form of the curve of the binomial coefficients of the expansion $(1+x)^{2n}$ when n is very large.

Before further considering this proof, I shall briefly refer to two more proofs of the law of error.

FIFTH PROOF.

In the first and second of the above proofs the errors of the observations are looked upon as *bulk* errors, subject to variation in a continuous manner, *i.e.*, to increase or decrease by infinitesimal variation.

In the third proof the errors are supposed to be made up of infinitesimal elementary errors, each having two values, equal but of opposite sign.

In the fourth proof the errors are also supposed to be two-valued, of equal and opposite sign, but of finite magnitude (until the final approximation is made).

In a proof given by Professor Crofton in the *Encyclopedia Britannica*, the elementary errors are supposed to be of finite magnitude, and capable of taking many values. The basal assumption is that these elementary errors, though finite, are small, so that each enters into the result only by its mean value and the mean value of the squares of its different values. His proof is based upon certain differential equations which must be satisfied in order that the entrance of a new error may change the constants, but not the form, of the law of frequency.

His proof I shall not give here, but will, from his hypothesis of finite elementary errors having many values, arrive at a proof in a different way, thus :—

Let the error x of an observation be made up of errors e_1, e_2, &c., so that

$$x = e_1, + e_2 + \&c.$$

Suppose e_1 to take n values during the series of observations and let m represent their mean, and μ^2 the mean of their squares.

Then so far as the error e_1 is concerned it enters into the value of x by its mean value m, which is of the nature of a constant error, which we cannot eliminate. The individual values of e_1 will enter into the mean square error of x, by their differences from the mean, just as in the first proof, that is in a probability curve,

$$y = \frac{1}{\mu\sqrt{2}} e^{-\frac{x^2}{2\mu^2}}.$$

Thus the value derived from the mean of the series of observations will be equal to :—*True value* + m_1 + m_2 + . . . , that is, *True value* + *the constant error* of the series.

This result will be subject to the law of error derived by combining the separate laws

$$y = \frac{1}{\mu_1\sqrt{2}} e^{-\frac{x^2}{2\mu_1^2}} ; \; y = \frac{1}{\mu_2\sqrt{2}} e^{-\frac{x^2}{2\mu_2^2}} ; \; \&c.$$

How these separate laws may be combined will be shown further on.

SIXTH PROOF.

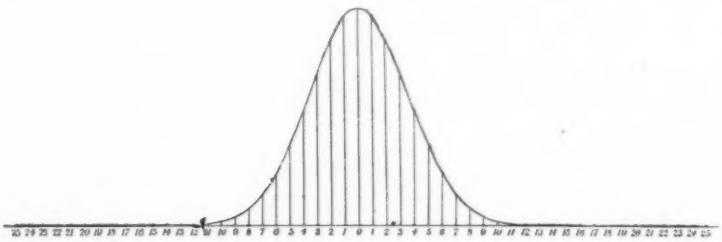
In this proof it is supposed that a ball is dropped with the intention of hitting a given point on a horizontal plane. If we assume two axes at right angles drawn through the point, the chance of the ball striking the plane between the distances y and $y + dy$ from the axis of x may be expressed by $\varphi(y^2)dy$, an even function of y, since positive and negative errors are equally likely. Similarly the chance that it falls between x and $x + dx$ is $\varphi(x^2)\,dx$. Hence the chance that it falls on a small area $dxdy$ at the point

(x, y) is $\varphi(x^2)\varphi(y^2)d\sigma$, $d\sigma$ representing the element of area. Since this is independent of the direction of the axes, we may suppose that direction changed, the origin remaining the same. The new coördinates of the point (x, y) being represented by x_1, y_1 we have for the probability $\varphi(x_1^2)\varphi(y_1^2)d\sigma$.

Hence $\varphi(x^2)\,\varphi(y^2) = \varphi(x_1^2)\varphi(y_1^2)$, with $x^2+y^2 = x_1^2+y_1^2$.

The solution of this equation is the usual exponential form.

The weak point in this proof is the assumption that the falling between x and $x+dx$ from the axis of y, and the falling between y and $y+dy$ from the axis of x are independent events, whose respective probabilities are to be multiplied together to give the probability of their simultaneous occurrence. It would seem that, if the origin is aimed at, the two events are not independent; the chance of falling on the area $dxdy$, or $d\sigma$, would be $\varphi(r^2)d\sigma$, or $\varphi(x^2+y^2)\,d\sigma$, the probability depending solely on the distance from the origin. From $\varphi(x^2+y^2)d\sigma$ as the expression of the probability, no deduction as to the form of φ can be drawn by change in the direction of the axes.



REMARKS ON FOURTH PROOF.

The curve shown in the diagram is the binomial curve, drawn through the extremities of equidistant ordinates which are proportional to the coefficients of the expansion of $(1+x)^{2n}$.

In the construction of the diagram, $2n$ has been taken equal to 50, that is to say we have drawn the curve of probability for 50 elementary errors, any one of which may be positive or negative. Notice the points of inflexion on each side of the central

ordinate at a distance of about 3½ units from it. Each unit represents the sum of two of the elementary errors. I have here a table of the coefficients of the binomial expansion, made by multiplication. (See below for table).

Now we have as the equation of the probability curve

$$y = \frac{h}{\sqrt{\pi}} e^{-h^2x^2}.$$

Differentiating this twice, we have $\frac{d^2y}{dx^2} = 0$ when $x = \frac{1}{h\sqrt{2}}$, showing that there is a point of inflexion. The symbol μ is generally used for $\frac{1}{h\sqrt{2}}$.

The equation of the probability curve as derived from the hypothesis of n elementary two-valued errors is

$$y = \frac{1}{\sqrt{n\pi}\, dx} e^{-\frac{m^2}{n}}.$$

Comparing this with the other we see that

$$\mu = \sqrt{\frac{n}{2}}\, dx$$

therefore when n as in the figure is 25, μ is equal to $\frac{5}{\sqrt{2}}$ × unit of abscissas = 3·5 times this unit, agreeing with the diagram.

If we add together the squares of all possible errors and divide by their number we get the mean of the squares.

This is the same thing as multiplying the square of each possible value of the error by its frequency, or probability, and adding them together.

In the probability curve this will mean the summation of all quantities such as

$$\frac{h}{\sqrt{\pi}} x^2 e^{-h^2x^2}\, dx.$$

By the Integral Calculus the sum is

$\frac{h}{\sqrt{\pi}} \int_{-\infty}^{\infty} x^2 e^{-h^2x^2}\, dx$, which is equal to $\frac{1}{2h^2} = \mu^2$ so that μ, the abscissa of the point of inflexion is equal to the square root of

the mean of the squares of all errors. In the binomial curve, we get the mean of the squares by multiplying the coefficients of the expansion of $(1+x)^{2n}$, that is

$$1+2nx+\frac{2n(2n-1)}{\lfloor 2}\,x^2+\ldots\ldots+2nx^{2n-1}+x^{2n}$$

by the terms representing the squares of the respective errors corresponding to these coefficients, that is,

n^2dx^2, $(n-1)dx^2$, $\ldots\ldots 1^2dx^2$, 0^2dx^2, 1^2dx^2 $\ldots\ldots$ $(n-1)dx^2$, n^2dx^2,

and dividing by the total number of errors, that is, by

$$1+2n+\frac{2n(2n-1)}{\lfloor 2}+\ldots\ldots\ldots=2^{2n}.$$

Hence we get

$$\frac{dx^2}{2^{2n}}\left\{n^2+2n(n-1)^2+\frac{2n(2n-1)}{\lfloor 2}(n-2)^2+\ldots\ldots\right\}$$

which may be shown by algebra to be equal to $\frac{n}{2}\,dx^2$.

Hence $\mu=\sqrt{\frac{n}{2}}\,dx$, agreeing in this case also with the abcissa of the point of inflexion.

μ is hence called the mean square error.

The formula $\mu=\sqrt{\frac{n}{2}}\,dx$ gives us a physical interpretation of the mean square error, on the assumption that an error is made up of a great number of elementary errors.

For ndx is the greatest possible error, dx the least (except zero).

Hence μ is the geometrical mean between the middle positive error $\left(\frac{n}{2}dx\right)$ and the least positive error.

Or, as shown above, $dx=2\varepsilon$ where ε is the elementary error. Hence $\mu^2=2n\varepsilon^2=2n\varepsilon\times\varepsilon$, and μ is the geometrical mean between the greatest possible error and the elementary error.

We may now show how partial errors may be combined, that is to find the law of error of $x=e_1+e_2+e_3+\ldots$ where e_1, e_2, &c. follow the laws, respectively,

$$y=\frac{h_1}{\sqrt{\pi}}\,e^{-h_1^2x^2},\quad y=\frac{h_2}{\sqrt{\pi}}\,e^{-h_2^2x^2},\text{ etc.}$$

Let us first consider two errors e_1 and e_2. Let e_1 be composed of $2n$ elementary errors ε, and e_2 of $2q$ elementary errors of the same magnitude ε.

Then the probabilities of the different values of e_1 are the coefficients of $\frac{1}{2^{2n}}(1+x)^{2n}$, and those of the different values of e_2 the coefficients of $\frac{1}{2^{2q}}(1+x)^{2q}$.

The first of these series expanded is

$$\frac{1}{2^{2n}}\left(1+2nx+\frac{2n(2n-1)}{\lfloor 2}x^2+\ldots\ldots+\frac{\lfloor 2n}{\lfloor n-m}\,\frac{}{\lfloor n+m}x^{n-m}+\&c.\right)$$

and the probability of an error $2m\varepsilon = mdx$ is the coefficient of x^{n-m}; the probability of an error $(m-1)dx$ = coefficient of x^{n-m+1}; of $(m-2)dx$, coefficient of x^{n-m+2}; and so on.

In the expansion of $\frac{1}{2^{2q}}(1+x)^{2q}$, the probability of an error pdx is the coefficient of x^{q-p}, that of $(p+1)dx$ is the coefficient x^{q-p-1}; of $(p+2)dx$ is the coefficient of x^{q-p-2}; and so on.

Now an error $m+p$ in e_1+e_2 may occur through an error m in e_1 with an error p in e_2; by an error $m-1$ in e_1 with an error $p+1$ in e_2; and so on.

It will be seen that if we multiply the two series,

$$\frac{1}{2^{2n}}\left(1+2nx+\frac{2n(2n-1)}{\lfloor 2}x^2+\ldots\ldots+\frac{\lfloor 2n}{\lfloor n-m}\,\frac{}{\lfloor n+m}x^{n-m}+\&c.\right)$$

and

$$\frac{1}{2^{2q}}\left(1+2qx+\frac{2q(2q-1)}{\lfloor 2}x^2+\ldots\ldots+\frac{\lfloor 2q}{\lfloor q-p}\,\frac{}{\lfloor q+p}x^{q-p}+\&c.\right),$$

together the several terms of the coefficient of $x^{n-m+q-p}$ in the product will represent the combined probabilities of error m in first with p in second; $m-1$ in first with $p+1$ in second; $m-2$ in first with $p+2$ in second; ..... $m+1$ in first with $p-1$ in second; and so on.

Hence the required probability of error $(m+p)dx$ in e_1+e_2 is the coefficient of $x^{n-m+q-p}$ in

$$\frac{1}{2^{2n}}(1+x)^{2n} \times \frac{1}{2^{2q}}(1+x)^{2q}$$

which equals

$$\frac{1}{2^{2(n+p)}}(1+x)^{2(n+q)},$$

a binomial exactly similar to $\frac{1}{2^{2n}}(1+x)^{2n}$.

Putting $n+q=n_1$, the probability of an error $m+p$ in e_1+e_2 is therefore the coefficient of $x^{n_1-(m+p)}$ in

$$\frac{1}{2^{2n_1}}(1+x)^{2n_1}$$

which shows that e_1+e_2 has a law of error of similar form to that of each of its constituents $n_1=n+p$. Whence if μ_1 and μ_2 represent the mean square errors of e_1 and e_2, and μ that of e_1+e_2

$$\mu^2=\mu_1^2+\mu_2^2.$$

If now an error e_3 with *m.s.e.* μ_3; an error e_4 with μ_4; and so on; be introduced, it is seen that the *m.s.e.* of $e_1+e_2+e_3+e_4+$ &c. is given by the formula

$$\mu^2=\mu_1^2+\mu_2^2+\mu_3^2+\mu_4^2+\text{ &c.};$$

and if $\mu=\frac{1}{\sqrt{2}h}$, the law of error for $e_1+e_2+e_3+$ &c. is

$$y=\frac{h}{\sqrt{\pi}}e^{-h^2x^2}, \text{ where } \frac{1}{h^2}=\frac{1}{h_1^2}+\frac{1}{h_2^2}+\text{ &c.}$$

This will serve to complete my proof of No. 5.

If, as above, we have

$$x=e_1+e_2+\text{ &c.}$$

and e_1, e_2, &c. are independent variables; and suppose

$$e_1=e_2=e_3=\text{ &c.},\ \mu_1=\mu_2=\mu_3=\text{ &c.},$$

then

$$x=ne_1,$$
$$\mu^2=n\mu_1^2.$$

But if e_1 is an observed quantity, and μ_1 its mean square error, then if we multiply all our results by a factor n, the m.s. error is $n\mu_1$,

$$\text{or } x = ne_1,$$
$$\mu^2 = n^2\mu_1^2;$$

for multiplying the errors by the factor n does not alter their relative frequencies, but merely changes the scale of the line of abscissæ, and the abscissa of the point of inflexion is multiplied by the same factor.

Hence if we have r observed quantities $e_1\ e_2 \ldots e_r$, each having m.s.e. $= \mu_1$ the m.s.e. of their sum x is $\mu_1\sqrt{r}$ and the m.s.e. of the arithmetic mean

$$= \frac{\mu_1\sqrt{r}}{r} = \frac{\mu_1}{\sqrt{r}}.$$

Again if we define the weight of an observation as equal to the number of standard observations to which it is equivalent in precision, and since we then have $\mu^2 = \frac{\mu_1^2}{r}$, the weights of observations are inversely proportional to the squares of their m.s.e.'s.

But $\mu^2 = \frac{n}{2}dx^2$, whence the weight of an observation is measured by the reciprocal of the number of elementary errors which enter into it.

With regard to the value of the part of the exponenent in Proof 4 which has been neglected, the whole exponent of e was found to be

$$-\frac{m^2}{n} - \frac{m^2}{n^2}\left(\frac{1}{6}\frac{m^2}{n} - \frac{1}{2}\right) - \frac{m^4}{n^4}\left(\frac{1}{15}\frac{m^2}{n} - \frac{1}{4}\right) - \&c.$$

By taking $-\frac{m^2}{n}$ alone, we have derived the probability

$$\frac{1}{\sqrt{n\pi}}e^{-\frac{m^2}{n}}.$$

We have multiplied the true value by e to the power of

$$\frac{m^2}{n^2}\left(\frac{1}{6}\frac{m^2}{n}-\frac{1}{2}\right)+\frac{m^4}{n^4}\left(\frac{1}{15}\frac{m^2}{n}-\frac{1}{n}\right)+\&c.$$

This is very nearly unity when m is small compared with n, that is near the centre of the curve. Very few observations have an error greater than 3μ; this is shown by the fact that the curve beyond $\pm 3\mu$ practically coincides with the axis of x.

When

$$mdx=3n=3\sqrt{\frac{n}{2}}\,dx, \text{ or } \frac{15}{\sqrt{2}}\,dx$$

in the curve shown in the diagram, that is practically at the limit of the curve, the neglected part of the exponent will represent a factor $e^{\cdot 14}$ about or $1\cdot 15$, so that at this point our approximate formula gives a probability about one seventh greater than it should be.

Throwing out the factor

$$\left(1-\frac{1}{8n}-\&c.\right)$$

also increases the probability by about $\frac{1}{200}$.

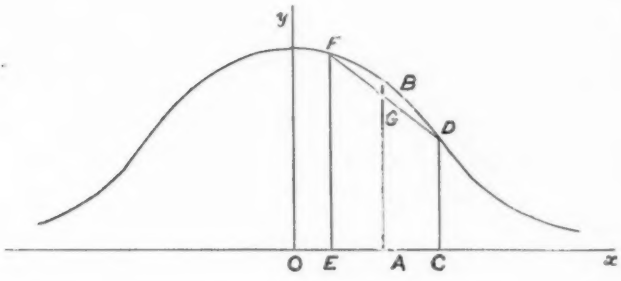
At the middle of the curve, when $m=0$, the former error is 0, the latter $\frac{1}{200}$.

Hence the curve, when n is finite, and no greater than 25, closely agrees with the curve for $n=$ infinity.

Let us consider the effect upon the probability curve of a large error entering, $=\pm a$. Suppose it to occur in every observation, as often plus as minus.

Any error $x=OA$ is now replaced by $OC-a$ half as many times as OC occurs, that is, in proportion to half the ordinate CD, and by $OE+a$, a number of times proportional to $\frac{1}{2}EF$.

Join DF, cutting AB in G. It is evident that AG is the frequency now of the error OA, and that G falls below the curve.



This will happen for all points between Oy and the point of inflexion, or thereabouts, while beyond the point of inflexion the new point will be further from Ox than the old.

Hence the effect of the bulk error $\pm a$ is to flatten the curve.

The new curve will not be a curve of the normal form when a is large. It will have a point of inflexion, but this point of inflexion will not coincide with the abscissa of the m.s.e., derived by summing the squares of the errors $(x \pm a)^2$ throughout the curve.

More of the area of the curve will be beyond the two ordinates of the m.s.e. Hence the tendency of errors of this kind is to increase the proportional number of large residuals.

Other forms of large errors, such as periodical errors may be tested in the same way. A periodic error, assumed to take all values between its maximum and minimum limits, will replace the original ordinate by an ordinate which is the mean ordinate of the curve between ordinates distant from the original ordinate by the amount of the + and − maximum periodic error. This mean ordinate, when the abscissa is less than the m.s.e. will be less than the original ordinate. Hence the probability of small errors will be diminished, and of large errors increased, since total probability = 1, and, therefore, total area of curve remains the same.

Numerical Values of Binomial Coefficients of $(a+b)^{50}$.

No.	
1	1
2	50
3	1,225
4	19,600
5	230,300
6	2,118,760
7	15,890,700
8	99,884,400
9	536,878,650
10	2,505,433,700
11	10,272,258,670
12	37,353,738,800
13	121,399,651,100
14	354,860,518,600
15	937,845,656,300
16	2,250,829,575,120
17	4,923,689,695,775
18	9,347,379,391,150
19	18,053,528,883,775
20	30,405,943,383,200
21	47,129,212,243,960
22	67,327,446,062,800
23	88,749,815,264,600
24	108,043,253,365,600
25	121,548,660,036,300
26	126,410,606,437,752 (middle term).

CHARLES A. YOUNG

(WITH FRONTISPIECE)

By Edwin B. Frost, in *Science* for January 24, 1908.

THE past five months have brought severe losses to astronomy in the deaths of five of its distinguished men; in Germany, Vogel, of Potsdam; in France, Lœwy, of Paris, and Janssen, of Meudon; in this country, Asaph Hall; and now Charles A. Young, who died at Hanover, N. H., on January 3.

There is some consolation, however, in the fact that all of these men had reached advanced years,* and had in a measure rounded out their scientific careers, although the three first named were still in active service as directors of large observatories.

Charles Augustus Young was born on December 15, 1834, at Hanover, where his grandfather and father successively occupied the chair of natural philosophy in Dartmouth College during the period from 1810 to 1858. He entered college early and graduated with distinction in 1853 as bachelor of arts. During his student days he assisted his father in astronomical observations and accompanied him in 1853 on a trip to Europe to purchase instruments for the Shattuck Observatory, then in course of erection. For two years after graduation he taught the classics at Phillips Academy, pursuing at the same time theological studies at the Andover Seminary. In 1857 he went to Hudson, Ohio, as professor of mathematics and natural philosophy at Western Reserve. During several summer vacations he assisted in the governmental survey of the great lakes. Responding to the call of patriotism in 1862, he was for four months Captain of Company B in the 85th Regiment of Ohio Volunteers, which was largely recruited from students.

In 1866 he returned to Dartmouth as professor of natural philosophy and astronomy, thus continuing the family tradition.

* Average age, 75 years.

The next few years were stirring times in astrophysical research. The spectroscope was just beginning to be applied in the study of celestial objects, with results of surprising interest. The eclipse of 1868 was made memorable by the discovery by Lockyer and Janssen of the method of observing the solar prominences. In spite of heavy duties as teacher, Young applied himself assiduously to solar research. He observed the eclipse of 1869 at Burlington, Iowa, establishing the fact of the gaseous nature and truly solar origin of the corona. Employing what was for those days a very powerful spectroscope, he quite accurately located the positon of the green corona line, which was thereafter known as No. 1,474 on Kirchhoff's map of the solar spectrum. It was not until the eclipse of 1898 that the position of the line was more correctly located, by Professor W. W. Campbell observing in India, and was shown not to be represented by a dark Fraunhofer line. At the eclipse of 1869 Young also looked for, but failed to detect, the reversal of the dark lines at the moment of internal tangency of moon and sun. But he realized his expectations at the Spanish eclipse of the next year, when he discovered the "flash spectrum." He describes it in these words: "The moment the sun is hidden, through the whole length of the spectrum, in the red, the green, the violet, the bright lines flash out by hundreds and thousands, almost startlingly; as suddenly as stars from a bursting rocket head, and as evanescent, for the whole thing is over within two or three seconds."* This phenomenon was subsequently observed visually in a more or less satisfactory way by different astronomers at other eclipses, but it was not photographically recorded until 1896, when it was caught by Mr. W. Shackelton at Nova Zembla with the prismatic camera.

In the early seventies Professor Young gave much attention to the spectrum of the chromosphere and to the prominences. Many of his delineations of these have become classics from their reproduction in various works and text-books. He devised an improved form of solar spectroscope which served his purpose

* *The Sun*, p. 82.

very effectively. His assiduity was rewarded by his observation of a number of rather unusual solar phenomena: such as the highest recorded prominences, extraordinary velocities indicated by distorted lines, up to 320 miles per second; violent solar agitation associated with magnetic storms. He was the first to attempt to photograph the prominences and attained a partial success (1870). With the wet plates then necessarily employed an exposure of four minutes was necessary with the use of the dark blue line of hydrogen (H_γ). This degree of insensitiveness of the films made it undesirable to spend time on such photographs.

In 1876 he made the first use of a grating spectroscope in astronomical work, and measured the rate of rotation of the sun by the displacement of the lines at the east and west limbs.

Professor Young successfully observed the transit of Venus of 1874 at Peking, and went to Russia for the eclipse of 1887, but was prevented from work by clouds. He had clear skies at the eclipse of 1878 at Denver, and in 1900 at Wadesboro, N. C. He also particularly studied the chromospheric lines, and made a list of 190 which he had noted with the spectroscope attached to the Dartmouth nine-inch telescope. The advantage of a high elevation becoming evident, he made an expedition in the summer of 1872 to Wyoming, where with the apparatus taken from Hanover, at an elevation of 8,000 feet, he added another hundred lines to his list. The subsequent increase in these lines, aside from those found in eclipse photographs, has been chiefly due to his own observations at Princeton.

In 1877 he accepted a call to Princeton, where much larger instrumental facilities were offered to him, with less confining teaching duties. He gave, however, much time to the organization and equipment of the students' observatory, making it then probably the best in this country. A powerful spectroscope was provided for the 23-inch equatorial of the Halsted Observatory, and with this he made important observations of the chromosphere and sunspots. He discovered in 1883 that the absorption spectrum of the sunspot umbra may be resolved into "countless

and contiguous" dark lines, a difficult observation later amply confirmed by others. With the Halsted refractor he also made micrometric observations of planets and satellites. He carried out an extensive program of observations of the transit of Venus in 1882 at Princeton.

His admirable work "The Sun," of the International Scientific Series, appeared in 1881 and presented in a clear and interesting manner the known facts and theories of solar physics. It includes many of his own interpretations of difficult points and is the authoritative work on the subject. It is characteristic of his modesty that many ot his own discoveries (such as that of the reversing layer) are there given without mention of his own name, and would only be recognized as such by those familiar with the circumstances, who could read between the lines, or by those who happened to consult the index. Several editions of this work appeared, and it was translated into several foreign languages. The last, thoroughly revised, edition was published in 1895.

His "General Astronomy," the first of his important series of text-books which have been used by more than a hundred thousand students, was issued in 1888. It represents much more than a mere text for students, and has been widely used as a work of reference. The "Elements of Astronomy" and "Lessons in Astronomy," adapted for more elementary students, were published a little later. The "Manual of Astronomy," comprising most of what was in the "General Astronomy," but with more illustrations and with the inclusion of the latest data, was issued in 1902.

The fundamental idea in Professor Young's text-books, popular articles and lectures, was that statements should be accurate as far as they go. He was no special pleader, and in his public utterances always fairly stated both sides of disputed matters, and he avoided controversy in a manner exemplary to younger men. His public lectures were not popular by reason of any eloquence of delivery or of rhetorical skill, but because of their clearness, simplicity and convincing quality of accuracy.

As a teacher he was particularly successful; having himself a splendid grasp of the fundamentals of mathematics and physics, he presented his subject logically, with emphasis on the essentials; and his humor enlivened the class room. It is doubtful if any teacher in this country has enlarged the intellectual horizon of a greater number of undergraduates than has he, in his culture courses in astronomy. "Twinkle" will never be forgotten by any of his students.

Professor Young's eminent services in research and education received recognition in numerous academic degrees, membership in and awards from various learned societies.

He had suffered from Bright's disease for a number of years; but by good care had kept himself fairly comfortable. The loss of his wife seven years ago, after forty-four years of a particularly happy married life, came as a crushing blow to him; and to his sorrow was lately added the death, after a year of distressing illness, of his widowed daughter, who made her home with him.

The retirement from his position at Princeton in the summer of 1905 was made the occasion of a grateful recognition by his colleagues, and the appreciation shown by his friends at that time must have been a source of much gratification to him. He then returned to Hanover, where he lived quietly, until he succumbed to a brief attack of pneumonia on January 3. Two days later he was gathered to his fathers in the old cemetery close to the house where he was born.

YERKES OBSERVATORY,
January 14, 1908.

THE VARIABILITY IN LIGHT OF *MIRA CETI* AND ON THE TEMPERATURE OF SUN-SPOTS.

By I. J. Kavanagh

IT is refreshing to be assured that on the Sun, it is not equally hot all the time and everywhere. That on the Sun there are regions relatively cool, if not absolutely balmy, is the conclusion of Father Cortie, S.J., F.R.A.S., of Stonyhurst, in the *Astrophysical Journal* of September, 1907. He shows that if we may ascribe to temperature, as we do, the observed differences in stellar spectra, it should be easy to admit the existence of a lower temperature in sun-spots as compared with that of the photosphere; and this all the more easily if the argument be founded on the influence of the same substance on the stellar and sun-spot spectra.

The well named *Mira Ceti* is a variable which has received long and richly rewarded attention at Stonyhurst Observatory. Its spectrum, which contains a series of dark bands due to titanium oxide, puts it under Secchi's III. Type. The existence of such flutings in spectra is attributed to the presence of compound bodies. Adequate increase of temperature would split these up, with the consequent production of line spectra; intermediate temperatures would produce intermediate spectra, with more or less condensation into line appearance. As, however, such dissociation occurs at different temperatures for different bodies, one cannot argue from the appearance of flutings to conditions of temperature, unless it be in the case of the spectrum of the same substance.

In the variations in *Mira's* brilliancy the spectrograph reveals a steady sharpening of the heads of the flutings and a shortening of the winged extensions, with the rise in the scale of visibility.

Comparing the splendid series of spectrograms, five of the maxima of 1907 and 1906, (the latter being the brighter by one

magnitude), these spectrograms, taken by Father Sidgreaves under absolutely identical conditions as to the plates and instruments employed, exhibit in the spectrum of the more brilliant maximum of 1906, a more marked tendency towards the line-spectrum of dissociation temperatures than in that of 1907. Now as these very titanium oxide bands have been observed in the spectrum of sun-spots, especially at periods near and at maximum spot activity, we may, in all consistency, conclude that at these points of the solar surface the heat does not reach as elsewhere the temperature of total dissociation, and that, therefore, the temperature of sun-spots is lower than that of the solar photosphere. Some of the useful references given by Father Cortie are here inserted :—

Astrophysical Journal, *25*, 77, 1907,

Monthly Notices, *67*, 482, 1907, *58*, 344, 1898,

JOURNAL of the R.A.S. of Canada, Mr. J. S. Plaskett, *1*, 56, 1907.

MEETINGS OF THE SOCIETY

AT TORONTO.

December 10, 1907.—Mr. T. Harold Parker, B.A., Ivy P.O., Ont., was elected a member of the Society.

Mr. J. C. Boyce read some notes which had recently been published bearing on the subject of the theories advanced in Mr. Collins' paper given at the last meeting on "Modern Theories of the Evolution of Matter."

The paper of the evening was by Mr. W. E. Jackson, M.A., on "A Review of some recent Views on the canals of Mars," and referred chiefly to the discussion on this subject carried on in recent numbers of the *Astrophysical Journal* by Professor Newcomb and Professor Percival Lowell. Mr. Jackson explained, Professor Newcomb's argument that from defects inherent in the telescope, it is physically impossible to produce on the image of the planet the fine markings seen on many drawings. From data and formulæ relating to aberration he deduces that with our best refractors we cannot expect in practice to bring more than one-fourth of the light of a star within a circle of radius one-tenth of an inch. In a star's image the intensity diminishes rapidly as we go out from the centre, though in the image of a bright line this diminution will be less rapid. In this way the image of a dark line on a bright background will have its edges indefinite. From the psychological point of view it was noted that the eye does not perceive what is actually pictured on the retina, but it unconsciously introduces a correction based on previous experience, and this error will be more important as the object approaches the limit of visibility. Experiments with drawings seemed to confirm these conclusions. Newcomb also attempted to calculate the space on the planet's disc covered by the 400 canals enumerated by Lowell, and concluded that they should spread over three-fifths of the area. On the other hand Professor Lowell attacks the validity of Professor Newcomb's

theoretical formulæ and quotes experiments to show their incorrectness.

The discussion on the subject was interesting, and the unfortunate disagreement among very competent observers was given as a reason for suspending judgement as to the objective reality of the canals.

December 17.—The following were elected members of the Society:

James McEachren, Toronto,
Stanley Lindsay, Montreal.

Mr. A. Sinclair, the Librarian, presented a summary of the number and nature of the papers presented to the Society during the last seventeen years. This was a valuable statement and will appear later in the JOURNAL.

The paper for the evening was by Mr. John A. Paterson, M.A., K.C., on "The Apex of the Sun's Way." The manner in which the motion of the solar system in space by the apparent opening-out and closing-in of the stars in opposite parts of the sky, as well as an outline of the researches made by the astronomers from Sir William Herschell onwards was presented. It has been well determined that our system is moving toward a point not far from the bright star Vega in the constellation Lyra at the rate of 12 miles per second.

January 14, 1908.—The Annual At Home of the Society took place in its rooms in the Canadian Institute building, the accomodation being taxed to the limit. The chair was occupied by the President-elect, Mr. W. B. Musson.

The following were nominated for membership:

T. A. Chapman, Baltimore, Ont.
(proposed by D. B. Marsh and C. A. Chant).

Saul Dushman, B.A., University of Toronto, Toronto,
(proposed by H. P. Mills and C. A. Chant).

By unanimous agreement the by-law requiring two weeks to elapse between nomination and election was suspended, and the two gentlemen were at once elected members.

The retiring President, Dr. Chant, then gave a review of the "Progress of Astronomy and Astrophysics" during 1907. The address was most admirable, giving the result of elaborate investigations into the subject, and was heard with much pleasure by the large audience It appears in the present number of the JOURNAL.

At the close of the address it was moved by Mr. John A. Paterson, K.C., seconded by Mr. R. Stewart Muir,

AND RESOLVED: That we record our deep sense of indebtedness for the able and faithful service that Professor Clarence A. Chant, M.A., Ph.D., has performed for this Society.

As our President for four years and a member for many years we have had the benefit of his advice and guidance in Council, his work on editing our JOURNALS and yearly HANDBOOKS, to all of which he has given valuable time, unstinted labor and professional skill.. He has not only been good, but also good for something, moreover good for much. He has taken hold of the work, not with the red tape of duty, which is something, but has touched it with the white silken cord of love, which is everything. The man that loves his work and does it because he loves it will do more than he who runs simply on the moral rails of formal duty. For all this we tender our gratitude to the retiring President, and wish him every advancement in his professional work, and happiness in all that makes life a joy and a benediction. (Carried).

The meeting was then thrown open, the time being spent in examining the admirable charts and photographs displayed, and in social intercourse. Refreshments were also served.

January 28.—Attention was called to the fact that Venus is conspicuous in the western sky, and that maximum brilliancy will be attained about the end of May. (Reference may be made to the *Handbook*).

Mr. R. Stewart Muir gave an interesting account of a recent visit he had made to the Dominion Observatory, Ottawa, where he spent a pleasant and profitable evening by courtesy of the Director and his staff.

The paper for the evening was by Dr. C. A. Chant, and gave an account of the Spiral Nebular Hypothesis of the solar system. Arguments in favor of the Laplacian theory were enumerated and attention was drawn to the difficulties which have accumulated in the way of its acceptance. Then a general statement of the Spiral Hypothesis developed by Professors Chamberlain and Moulton was given. This has been found not inconsistent with any known facts, and future work upon it may cause it to displace the old hypothesis. The paper was illustrated by many striking photographs of spiral nebulæ made at the Lick and Yerkes Observatories. E. A. D.

AT OTTAWA.

December 5, 3 P.M.—Dr. King asked the Vice-President to take the chair, while he read his paper on the "Geometry of Orbits." After referring to the method of obtaining the velocity curve from the observations, the methods of obtaining the elements of the orbit by the application of the hodograph were considered. Dr. King showed that when the motion is in an ellipse around a centre of force at the focus the hodograph is a circle turned through an angle of 90°. This circular hodograph becomes elliptical when the inclination of the orbit plane is taken into account, and Dr. King by an ingenious device showed how it could again be reduced to a circle.

The practical application of the hodograph to determine the elements of an orbit was next developed, the preliminary value of the eccentricity being obtained by a short computation and this being used to obtain closer approximations. In actual practice one period of the curve of oscillation is divided into an equal number of parts, in this case 40, and the ordinates corresponding to these abscissæ are set off on the circumference of the hodographic circle whose diameter is equal to the difference between the positive and negative maxima of the velocity curve. The ratio between the largest and smallest arcs on this circle gives the approximate value of e above referred to, and the final value, with the longitude of the apse, is given by comparing special protract-

ors with the divisions of the hodographic circle. Such protractors are constructed for every desired value of the eccentricity having as angles the true anomalies (for the given value of e) corresponding to mean anomalies of 9° or one-fortieth of the period. Dr. King then showed by means of a velocity curve with $e=0{\cdot}6$, $\omega=60°$, and the corresponding hodographic circle, how closely the eccentricity and the apsidal angle could be obtained.

The application of this method to the drawing of an ephemeris was then given and it was shown how simply the velocity curve for any given elements could be drawn. This ordinarily requires very laborious computations, while with the new method the whole procedure is graphical.

Dr. King described further ingenious applications of the method by which the ephemeris could easily be altered for a change in ω and pointed out other methods for shortening the work. He concluded by developing, in a graphical way, properties of the velocity curve such as the equalities of areas above and below the axis which had previously only been obtained analytically. The lecture was fully illustrated by diagrams and was listened to with close interest by the numerous members present.

Mr. Plaskett spoke of the pleasure with which he had listened to the paper, and explained to the members, what they certainly would not gather from anything that Dr. King had said, that the whole paper was not only original but was also most ingenious. It was also very practical and would much shorten the labor involved in obtaining the elements of an orbit.

December 19, 8 P.M.—The first Annual Meeting was held in the Carnegie Library Lecture Room.

The following officers were elected for the ensuing year :

President.—W. F. King, LL.D.,

Vice-President.—Otto Klotz, LL.D.,

Secretary.—J. S. Plaskett, B.A.,

Treasurer.—R. M. Stewart, M.A.,

Council.—Joseph Pope, C.M.G., F.R.S.C.,
A. H. McDougall, B.A.,
F. A. McDiarmid, B.A.

A vote of thanks was tendered to the officers for their services during the past year.

January 16, 8 P.M.—Dr. King read a paper on "The Calendar." He began by referring to the astronomical events that were used in ancient times to mark the passage of time, the principal of these being the day, the lunar month and the calendar or solar year. After the day, probably the first used was the lunar month of 29½ days. As civilization progressed, however, a longer interval was required and the changes of the seasons recurring once a year seems the natural interval to choose. A great deal of time and energy was expended in trying to make the lunar month fit into the solar year, and many ingenious and also cumbrous devices were introduced for that purpose. The final result, however, was to discard the lunar month altogether, using an arbitrary subdivision of the year into twelve months. An interesting account of the calendars employed by the Aztecs and Peruvians was given, the former being correct to 4¼ hours in a century.

Dr. King then explained the development of the calendar at present in use and gave the amusing history of the irregularity in the lengths and order of the months due to the pride of Augustus, who would not allow himself to be outdone by Julius Cæsar.

The Julian Calendar considered the year as 365¼ days, whereas it is only 365·2422 days, so that in 128 years the time of the equinox would have receded one day. By 325 A.D. it had receded 4 days. In this year the rule for the date of Easter was formulated by the council of Nice. It was to be celebrated on the first Sunday following the fourteenth day of the moon which fell on or next following the 21st of March.

By 1582, A.D. the equinox had retrograded to March 11th and in that year Pope Gregory XIII. ordered ten days to be suppressed in the calendar to bring back the equinox to March 21, and introduced the well known leap year rule regarding the last year of the centuries.

The Gregorian Calendar is so nearly exact that the equinox

will retrograde only one day in 3448 years. After speaking of the disturbance which took place in England when the Gregorian Calendar was introduced in 1752, Dr. King described fully the rules and tables used for finding the date of Easter, illustrating by examples for the present year. The derivation and explanation of the terms used, such as Sunday letter, Golden Number, etc., was fully given. The basis of these rules is the Metonic Cycle of 19 solar years after which the same day of the lunar month recurs on the same day of the year. The Julian period which is used in astronomy is also based on this cycle, and Dr. King concluded by explaining how the period was obtained.

For the Question Box, three questions had been handed in.

1. Explain the Precession of the Equinoxes.
2. What is the Libration of the Moon and explain the cause?
3. Explain the phenomenon of the Harvest Moon.

These questions were satisfactorily answered by Dr. Klotz, Dr. DeLury and Mr. C. A. French, repectively.

January 30, 3 P.M.—Mr. R. M. Motherwell presented a paper on the "Prediction of Occultations." It began by a brief discussion of the general theory of eclipses and occultations, and an explanation why the prediction of occultations is much simpler than the prediction of eclipses. The analytical method of predicting occultations was first dealt with. The fundamental plane, which passes through the Earth's centre perpendicular to the line from the star to the Moon's centre, is the plane of xy. The position of the observer and the axis of the shadow cast by the Moon are found with reference to this plane, and in this way the distance of the observer from the centre of the shadow is determined. When this distance equals the radius of the Moon we have the beginning or ending of the occultation. This method involves laborious computing, and to obtain fairly accurate results the computation must be repeated, using the time obtained from the first computation as the approximate time in the second.

Mr. Motherwell explained how the work of computing occultations by this method may be somewhat lessened by the use of tables for any given station.

The paper then explained how this computation could be avoided by the graphical method of W. F. Rigge. The fundamental plane is here used, and the paths of the observer and the Moon's shadow are projected on it. A paper edge indicates the Moon's path and a transparent disc replaces the Moon. The times of immersion and emersion as well as the position angle are read almost directly. This is the method employed by Mr. Motherwell, and besides obtaining the required data for observing an occultation in about 10 minutes, it has always been found that the predicted and observed times agree to within a minute in all central occultations. Equally simple of manipulation and equally accurate are the graphic methods devised by Dr. King and Professor Dupuis, both of which were briefly explained.

Dr. King spoke of the able way in which the subject had been handled and described his first experience in observing an occultation. Dr. Klotz also referred to the difficulty of the subject and stated that one need not expect to master the question by hearing one paper. J. S. P.

AT PETERBOROUGH.

The regular meeting was held in the "green" parlour of the Y.W.C.A. on Tuesday evening, January 17. The President, Dr. Marsh, gave an interesting account of his observations, and methods of finding his meridian.

The following Officers were duly elected :

President.—Dr. D. B. Marsh,

1st Vice-President.—Mr. H. B. Collier,

2nd Vice-President.—Sheriff Hall,

Secretary.—S. W. Lowry,

Treasurer.—Dr. F. C. Neal,

Council.—Messrs. D. E. Easson, G. M. Rogers, H. O. Fisk.

The Treasurer's report showed the finances to be in good condition with a balance of $14.40 on hand.

Mr. Easson and Mr. Peters were appointed a Committee to draft a letter of condolence to Mrs. Wm. Pringle, on the death of her husband, our late Vice-President.

It was carried by a unanimous vote that the Society meet in the Y.W.C.A. parlour regularly at the rate of $1.50 per meeting.

Mr. D. E. Easson took the chair and Dr. Marsh then took up the subject of the evening, "The Planet Jupiter," and gave a very interesting address. S. W. L.

ASTRONOMICAL NOTES.

The Lick Observatory party which went to Flint Island, Southern Pacific Ocean, to observe the total eclipse of the Sun on January 3, returned to Mt. Hamilton on January 25. Rain fell during a part of the total phase, but the sky cleared and some excellent photographs were obtained, the instruments though wet working perfectly.

For many years Professor Lewis Boss, director of the Dudley Observatory, Albany, N. Y., has been engaged in the observation and reduction of a large and accurate fundamental catalogue of stars, and two years or more ago the proposal was made to extend this work to the southern hemisphere. The Carnegie Institution has offered to bear the expense of the proposed observatory, and Professor R. H. Tucker, of the Lick Observatory, will be placed in charge of it. It is expected that three years will be required to carry out the project and the station will be either in New Zealand, South America or South Africa. Professor Tucker, Mr. R. F. Sandford his assistant at Mt. Wilson, two from the staff of the Dudley Observatory and three others not yet chosen will leave in August for the new work. The large Pistor and Martins Meridian Circle of the Dudley Observatory will be used in the new work, and it is worthy of notice that it was with this instrument that Professor Tucker began his professional career, while his nine years of Service at the Argentine National Observatory at Cordoba will be of the highest advantage to him in carrying out the southern plan. Professor Tucker will retain his position at the Lick Observatory, being given leave of absence for the necessary time.

In the *Lick Observatory Bulletin No. 126* J. C. Duncan, describing his observations of Comet *d* 1907, remarks that "On the nights of August 8, 9, and 10, it was noted that, as the Nicol was rotated, the light of that part of the tail near the head, and that of the coma, underwent marked changes of intensity. The maximum intensity was reached when the plane of separation of

the ordinary and extraordinary rays in the Nicol was perpendicular to the apparent direction of the tail; showing that the light of the tail and coma was polarized in a plane containing the axis of the tail. No such effect was noticed in the light of the nucleus.

"On the night of August 12, Professor Campbell observed the comet's light with the same polarizing eye-piece applied to the finder of the 36-inch telescope, and found only a feeble variation of intensity; and on the night of August 13, I again observed a feeble variation. On all succeeding nights when the Nicol was used, no effects of polarization were observed in any part of the comet.

"The observations indicate that, from August 8 to August 13, and probably for some time preceding the former date, the light of the coma and tail consisted largely of diffused sunlight; that the proportion of proper to borrowed light increased about August 12 and 13; and that, after the latter date, the comet's own luminosity was sufficient to mask any polarization effects that may have been produced in diffused sunlight."

S. J. Corrigan is contributing a series of interesting articles to *Popular Astronomy* on "An Astronomical Theory of the Molecule and an Electrical Theory of Matter." The first of these series appeared in the December number of that journal.

Observations of the "knots" observed on Saturn's ring are described by R. H. Tucker in *Lick Observatory Bulletin No. 127*. "On the first of the two nights," he says, "the observing conditions were very bad, and the measures were made with difficulty. The light was condensed in four knots, and none of them appeared to be double. The measures are given in the order corresponding to that used above.

"On the last night, the sky was covered with cloud for the greater part of the night. During the short intervals of partially clear sky, the definition was good. Four condensations were seen, and these appeared much flattened. The shadow of the ring upon the planet was black, and sharply defined.

"Bad weather, since the end of November, has interfered with any further measures.

* * *

"The appearance of these knots and their development are evidently similar to those described by W. C. Bond, at the time the earth passed through the plane of the ring in 1848, and published in Volume 2, Part I, of the *Harvard Observatory Annals*. The knots at that epoch, however, appear to have been distributed with perfect symmetry, with respect to the planet; while the present series of measures place the Eastern ones closer to the planet."

Astronomische Nachrichten No. 4213 describes three series of observations of Professor Bohlin, of Stockholm, carried on since 1902, from which a first approximation to a measurable parallax of condensations in the Great Nebula in Andromeda was arrived at. The mean of the results is stated to be 0″·17. This would indicate the nebula to be about 17 light years from us. The diameter of the major axis of the nebula as seen from the earth, 2⅓° as given by Roberts, would indicate at that distance, a diameter in extent approximately 800 times greater than the solar system, or 4½ million million miles. Twenty-two of such systems as the Great Nebula, from its present position in space, placed edge to edge would on this basis about reach the solar system.

In the *Astrophysical Journal*, Vol. XXVI, No. 5, F. H. Loud of Colorado College advances a theory explanatory of short-period variability. He says:

"The best-known and most representative stars of the class under discussion, are then, stars of advanced development, and at the same time binaries of short period, in which as a rule one component only of the pair is luminous, for the spectral lines undergo no periodic duplication. According to the hypothesis to be tested, this component owes its light to the resistance of a diffused medium, to which the other must be assumed to be relatively at rest. The visible star, then, is the satellite; and at so

short a distance from the primary, the tides necessarily induced tend to impose upon it a rotation of equal rate with its revolution. The orbital movement, however, in parting with the energy which becomes the source of the star's visibility, is continually drawn into narrower compass, and thus accelerated in speed. The tidal action tends to restore the equality of the periods, with the result that the rotation is always a little—but only a little—slower than the revolution. The effect of this lag is that the area on the satellite, heated to brilliant incandescence, is of an unsymmetrical form. The point of greatest heating, since it occupies the momentary center of the advancing front, moves in consequence slowly around the equator, always entering upon regions comparatively cool, and drawing behind it regions glowing from their recent exposure to heat. Thus, as the revolution brings these regions successively into the line of sight, there appears first, to our view, a sudden rise of brightness, then, after the maximum, a long and gradual decline. The degree of cohesion in the surface, implied in this account, might well be too great for a star of Sirian tenuity, but not for the class of bodies actually concerned; especially if it be considered that both primary and satellite are presumed to have advanced far in condensation, with accompanying loss of light, the latter body being probably as dark as the former, save for the surface action of the resistance.

J. R. C.

SUMMARY REPORT OF WEATHER IN CANADA. DECEMBER 1907.

TEMPERATURE.—In British Columbia, over the northwestern and northern portions of the Province, the temperature was average or slightly below, elsewhere throughout the Dominion it was above the average and nearly everywhere to a marked extent. In the Western Provinces the positive departure ranged from 5 to 9 degrees; in Ontario from 2 to 7 degrees; in Quebec from 5 to 8 degrees, and in the Maritime Provinces from 3 to 8 degrees.

For highest and lowest temperatures see table below.

PRECIPITATION.—In British Columbia, Cariboo reported an excess of precipitation equivalent to nearly 90 per cent., but elsewhere in the Province there was a general deficiency amounting at Victoria to 52 per cent. In the Western Provinces, in the southern portion of Saskatchewan, there was a positive departure of 200 per cent. at Regina and 79 per cent. at Swift Current, otherwise the negative departure was everywhere marked; Winnipeg and Medicine Hat recorded deficiencies of 98 and 63 per cent. respectively. In Ontario the distribution of precipitation was very variable, some localities experiencing an amount much in excess of the average and others again much less than the average. The most noticeable extremes were positive departures of 98 per cent. at Toronto and 46 per cent. at Ottawa, and negative departures of 49 per cent. at White River and 94 per cent. at Port Arthur. In Quebec the average amount was exceeded in all localities, more so in the western than in the eastern portion; Montreal recorded 60 per cent. above the usual quantity. In the Maritime Provinces, in the region of the Bay of Fundy and very locally, elsewhere, the precipitation was less than the average, but over the large remaining portion of the Provinces the average was exceeded. The notable departures were a de-

ficiency of 39 per cent. at St. John and 79 per cent. at Chatham, and an excess of 25 per cent. at Halifax and Charlottetown.

DEPTH OF SNOW ON GROUND.—At the close of the year there was a remarkable absence in the Dominion of any pronounced depth of snow on the ground, and in many localities there was none. Considering the Provinces individually the conditions were in British Columbia, none on the low lands and apparently little on the mountains; Alberta none; Saskatchewan and Manitoba 1 to 6 inches; Ontario from a trace to 15 inches, whereas White River north of Lake Superior gave only 4 inches; Quebec from 5 to 11 inches; the Maritime Provinces, 1 to 3 inches in northern, and none in southern localities.

JANUARY 1908.

TEMPERATURE.—The mean temperature of the month was higher than average in all parts of Canada, exclusive of some of the eastern Counties of Ontario where there was a negative departure of from 1° to 3°. Near the coast in British Columbia the positive departure was from 1° to 3°, and eastward this increased to from 12° to 15° in Alberta, which differences also obtained in Saskatchewan and Manitoba. From the eastern boundary of Manitoba the positive departure from average gradually diminished to an excess of only 3° near Lake Huron, and in Southwestern Ontario the excess was between 1° and 3°. Over most of Quebec the positive departure was between 1° and 4°, and in the Maritime Provinces between 3° and 5°.

PRECIPITATION.—The precipitation was somewhat in excess of the average in Quebec and the Maritime Provinces and deficient in other parts of the Dominion. In British Columbia deficiency was small; in the Western Provinces it was approximately equal to about half the average amount.

DEPTH OF SNOW ON GROUND.—At the close of the month the Western Provinces had a covering of snow of from 2 to 5 inches, while in Ontario and Quebec there was from 6 to 30 inches of snow on the ground. In the Maritime Provinces the ground was bare in Eastern districts, and was covered to a depth of from 6 to 8 inches elsewhere.

TEMPERATURES FOR DECEMBER AND JANUARY.

STATION	December		January	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	20	-30	26	-42
British Columbia				
Agassiz	51	28	54	22
Atlin	36	2	34	-14
Barkerville	58	0	36	- 4
Cowichan	59	26		
Kamloops	52	12	48	4
New Westminster	56	22	48	18
Spence's Bridge			47	14
Vancouver			48	18
Victoria	56	28	50	26
Western Provinces				
Battleford	51	-19	46	-22
Calgary	57	- 8	50	- 8
Edmonton	59	-18	46	-25
Medicine Hat	64	- 8	50	-14
Minnedosa	42	-21	40	-42
Prince Albert	45	-26	36	-32
Regina	48	-20	40	-26
Swift Current	54	-12	42	-18
Winnipeg	41	-19	42	-35
Ontario				
Agincourt	47	5		
Bala	45	- 5		
Bancroft	45	-10	39	-47
Beatrice	44	- 6	37	-38
Brantford	49	9	42	-13
Bruce Mines	40	- 6	45	-26
Clinton			39	- 3
East Toronto			40	-20
Gravenhurst			39	-45
Haliburton	45	- 9		
Hamilton			46	- 8
Huntsville	45	- 5	37	-40
Kenora	41	- 4	40	-39
Kingston	48	2	39	-27
Lake of Bays			43	-43
Lake Talon			40	-44
Luchnow	48	- 2	38	- 7

STATION	December		January	
	Highest	Lowest	Highest	Lowest
Ontario (Cont.)				
Meaford	50	11	41	- 9
Otonabee	45	0		
Ottawa	44	3	37	-22
Owen Sound	47	13	42	- 7
Paris	48	10	40	-12
Parry Sound	45	- 2	40	-30
Peterboro'	47	- 6	40	-29
Port Arthur	41	-14	48	-31
Port Burwell	46	8	38	-11
Port Dover	49	10	48	-10
Port Stanley	47	5	39	-10
Rockliffe	41	- 8	36	-42
Southampton	50	14	41	- 6
Stony Creek	58	15	44	-12
Stratford	48	8	38	- 7
Sutton West	48	8	39	-24
Toronto	47	7	41	-14
Uxbridge	44	- 2	39	-29
Wallaceburg			41	-11
Welland	52	13	45	- 7
White River	40	-28	40	-46
Quebec				
Brome	50	-15	42	-21
Father Point	48	3	44	-11
Montreal	50	6	39	-20
Quebec	46	- 4	39	-22
Sherbrooke	50	-10	43	-20
Maritime Provinces				
Charlottetown	50	12	48	- 5
Chatham	57	5	47	-14
Fredericton	53	3		
Halifax	53	15	51	- 2
Moncton	57	0	52	-14
Port Hastings	50	10		
St. John	51	10	50	- 9
St. Stephen	56	- 3	50	-11
Sussex	56	- 6	54	-12
Sydney	57	20	54	4
Yarmouth	53	21	54	6

THICKNESS OF ICE.—Thickness of ice as reported from the various stations is as follows:—

Western Provinces.—Edmonton, 20 in.; Battleford, 24 in.; Medicine Hat, 18 in.; Swift Current, 27 in.; Minnedosa, 24 in.

Ontario.—White River, 8·5 in.; Southampton, 12 in.; Port

Stanley, 8 in.; Rockliffe, 18 in.; Ottawa, 30 in.; Arden, 17 in.; Renfrew, 16 in.; Sutton West, 10 in.; Georgetown, 15 in.; Port Burwell, 8 in.; Strathroy, 18 in.; Gravenhurst, 10 to 16 in.; Port Arthur, 10 in.; Bruce Mines, 24 in.

Maritime Provinces.—Chatham, 14 in.; Charlottetown, 8 in.; Sydney, 12 in.; St. John, 17 in.; Pt. Lepreaux, 6 in.

STATEMENT OF TEMPERATURE AND PRECIPITATION FOR TORONTO FOR THE YEAR 1907.

MONTH	TEMPERATURE			PRECIPITATION		
	Max.	Min.	Mean	Rain	Snow	Total
	°	°	°	in.	in.	in.
January	51·4	- 10·0	22·0	2·320	18·0	4·120
February	41·0	- 6·1	18·1	0·150	7·1	0·860
March	63·9	5.8	33·9	1·800	3·3	2·130
April	69·4	18.2	38·0	1·970	1·2	2·090
May	74·7	27·2	47·8	1·765	1·6	1·925
June	85·0	45·1	63·3	1·220		1·220
July	88·8	49·8	68·9	2·030		2·030
August	86·0	49·0	64·9	1·085		1·085
September	81·9	41·3	61·3	4·800		4·800
October	69·2	25·9	44·7	1·975		1·975
November	51.1	21·1	37·0	3·430	0·9	3·520
December	47·1	7·0	29.8	3·015	19·9	5·005
Year	88·8	- 10·0	44·1	25·560	52·0	30·760
Difference from average			- 0·1	-1·51	-14·6	-2·97